NOV 7 1987

83-B-4 A13.79: PSW-393

United States
Department of
Agriculture

Forest Service

**Pacific Southwest
Forest and Range
Experiment Station**

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Research Note
PSW-393
August 1987

Sediment Traps for Measuring Onslope Surface Sediment Movement

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Wells, Wade G., II; Wohlgemuth, Peter M. *Sediment traps for measuring onslope surface sediment movement.* Res. Note PSW-393. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987. 6 p.

Two types of small (30-cm aperture) sheet metal sediment traps were developed to monitor onslope surface sediment transport. Traditionally, sediment traps and erosion pins have been used to measure the onslope movement of surficial soil material. While pins may be appropriate for documenting landscape denudation, traps are more suitable for monitoring downslope transport parallel to the ground surface. Previous investigations used large (3-m aperture) traps to measure sediment transport. However, large aperture traps are cumbersome and require excessive amounts of time and energy for installation, sample collection, and sample processing. These serious logistical constraints make data acquisition difficult and expensive. The small traps were designed to remedy this situation. Field tests of these small traps revealed variable patterns of spatial and temporal surficial debris movement obscured in previous studies. Although these traps are not without limitations, the improved sampling logistics allow greater sample sizes and constitute a marked improvement over other transport measurement techniques.

Retrieval Terms: erosion measurement, sediment traps, surface erosion, hillslope erosion

The measurement of sediment movement on hillslopes is vital to studies of soil erosion, sediment production and landscape evolution. No truly satisfactory measurement technique has yet been developed, although numerous examples of several methodologies appear in the literature. These range from simple observation of hillslope features (such as the depth of soil pedestals under rocks and plants), to direct measurement of denudation (or deposition) by erosion pins and erosion bridges, to collection of the transported slope materials in sediment traps.

Sediment traps have been used in Forest Service research since the 1930's to measure the magnitude of hillslope sediment movement.[1] Initially, erosion was measured on fixed-area plots, and the size of the trap was determined by the dimensions of the plot. Typically, the width of the trap aperture ranged from 3 to 10 m. Data from some of these earlier studies suggest that sample standard deviations from these large traps were unexpectedly high, typically 50-100 percent of the sample means.[2] Moreover, the logistical constraints associated with these larger traps resulted in unacceptably small sample sizes, often to the point of no replication.

This note describes two types of small sediment traps used to measure surface sediment movement on steep, highly erodible slopes in the uplands of California. Because of their design the traps are believed to yield representative samples of transported material. Using these smaller traps makes larger sample sizes possible, and reduces project logistics significantly. The sample variability associated with these smaller traps is quite similar to that obtained from the larger traps. These advantages suggest that the smaller traps yield superior results for the same investment of resources, and are clearly the better technique for measuring surface sediment transport. Furthermore, these smaller traps, sampling smaller segments of a hillslope cross-section, are more sensitive to subtle erosion patterns, and can therefore be more closely linked to transport processes. By the analytical study of hillslope processes, we can begin to extricate ourselves from the "black box" which characterizes so many hillslope studies where inputs and outputs are recognized, but their causal interrelationships are not well understood.

THE PROBLEM OF MEASURING SURFACE EROSION

Surface erosion on hillside slopes is characterized in the short term by episodic pulses with a high degree of spatial variability.[3] Moreover, two aspects of surface erosion must be distinguished: downslope sediment movement parallel to the ground surface; and denudation or downwearing normal to the slope. Traditional techniques developed to document onsite hillslope erosion include pins and bridges to monitor denudation, and traps to measure sediment transport.

ORIGINAL

Erosion pins and erosion bridges measure changes in the elevation of the ground surface resulting from local slope denudation or deposition.[4] Pins typically consist of wooden stakes[5] or metal rods[6] driven into the ground either vertically or normal to the slope, often with rings or washers to aid in pin relocation and measurement standardization.[7] A variation of the pin technique is an erosion "bridge" or "frame," essentially a fixed mounting perforated with holes through which a dowel is lowered to measure changes in the ground surface level.[8]

The major problem with pins is that the data are often severely compromised by disturbance of soil during pin emplacement, and that hydraulic processes and normal transport patterns are disrupted by the mere presence of the pin.[4] These specific limitations are eliminated by the use of erosion bridges, but—because both pins and bridges record differences in surface micro-elevation—the data may still represent spurious ground level changes resulting from soil swelling, compaction, or illuviation.[9] There is no reliable way to separate these spurious data from those reflecting actual denudation or deposition. Another problem with pins and bridges is the inherent low sensitivity of their measurements. It is very difficult to realize greater precision than 1 mm, yet this 1 mm of possible error translates to sedimentation rates of 10 m^3 per hectare.

Sediment traps catch and retain soil material as it moves downslope.[10] These traps sample a fairly small portion of a hillslope cross section,[11] although installations traversing an entire hillside have been attempted.[12] While this method affords a direct measure of surface transport, it fails to delimit both the area contributing soil material and the thickness of the surficial layer in transit. Surface traps also do not detect downslope transport by groundwater action or wind deflation.

In earlier investigations of hillslope sediment transport, we used large (3 m) traps on plots bordered with lawn edging to delimit the contributing area. The results were mostly unsatisfactory. The traps were cumbersome and often did not fit the contours and the microtopography of the hillside. Considerable slope modification was usually necessary to set the traps flush with the ground surface. Even without a concrete approach apron,[12,13] each of these larger traps could often take hours to install. Besides the problem of artificial edge effects, plot borders were often undermined, attesting to the unpredictible sediment transport patterns on apparently homogeneous slope facets. Moreover, bordered plots only demarcate potential contributing areas, and there is no assurance that all regions within the plot are delivering sediment uniformly. Rather, the contributing area appears to be a function of the types, the timing, and the magnitude of process events.

From a purely theoretical standpoint, it can be argued that large traps will yield sample sets characterized by smaller dispersion about a mean value than will smaller traps. Sample spatial variability should increase as trap aperture is reduced, especially where rills are prominent on the landscape. In our previous investigations using large traps we have found that sample standard deviations are typically 50-100 percent of the sample means.[2] Duplicate plots situated side-by-side on a hillslope facet may exhibit an order of magnitude difference in sediment capture. This inherent variability in natural systems requires large sample sizes to obtain a reliable estimate of the true mean. Unfortunately, with bigger traps, this quickly creates logistical problems: gathering hundreds of kilograms of sediment from remote sites, then laboriously treating them in the laboratory. Thus, the logistics of plot installation, sample collection, and sample processing associated with larger traps often exceeds the limited resources of an individual investigator, usually causing a reduction in sample size to an unacceptable level.

SAMPLING METHODS AND TRAP DESIGN

Our current methodology is to measure slope movement using a large number of small (30 cm) sediment traps located on the studied hillslopes in some random or systematic fashion. The installation of each trap establishes a "borderless" plot of variable area on the hillslope above. The small trap size improves installation and collection logistics, thus allowing for a large sample size while keeping labor at a manageable level. Borderless plots eliminate the problem of unnatural edge effects but preclude the estimation of trap contributing area. However, such areal values—besides being extremely suspect—are usually employed in calculations of denudation rate and are therefore less useful to studies of onslope sediment transport. Rather, this arrangement of traps on borderless plots effectively samples the quasi-continuous downslope movement of the surface veneer of soil particles. The trap catch is measured as the weight or mass of the captured material, which can be converted to volumetric surface transport per unit slope width per unit time.

In the course of our research and development, we have designed two types of traps for different purposes and applications, and simply labelled them type 1 and type 2. The type 1 trap is constructed of bent and welded sheet metal (*fig. 1, 2*). Measuring 15 cm deep with a 30 cm by 10 cm aperture, this open trough is designed to be buried in the ground with an upslope apron flush to the slope surface. The lateral surfaces of the trap are angled upward 37 degrees so that the downhill side is 7 cm higher than the uphill side. This difference in height compensates for the loss of capacity experienced when the trap is mounted on an inclined surface. The apron is 25 cm wide and 15 cm long with a lip at the upper end to anchor it to the slope (*fig. 1*). Because of the width of the apron, the effective sediment collecting aperture of the trap is reduced from 30 to 25 cm. The raised lateral surfaces on the trough body keep sediment from entering the trap except across this apron. On the lower side of the apron is a slot that allows the trap to be lined with a plastic bag for collecting sediment (*fig. 3*). The bag also acts as a frontal barrier so that sediment can enter the trap body only across the approach apron.

The type 2 trap is also a sheet metal box with dimensions identical to those of the type 1 trap, but without the sloping lateral surfaces (*fig. 4-6*). Unlike the type 1 trap, however, this second trough is designed to lie flat on the hillside, which somewhat diminishes the trap capacity. Held in place by an apron anchored to the slope with long nails (*fig. 6*), the trap is secured to the apron by an overlapping flange and bracket assembly. This arrangement greatly facilitates sample collection, because the trough may be detached from the apron and its contents transferred directly

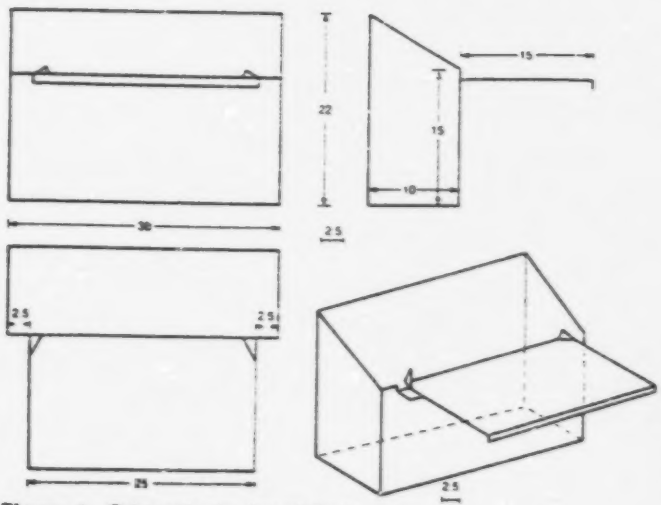

Figure 1—Schematic drawing of the type 1 trap with all dimensions in centimeters.

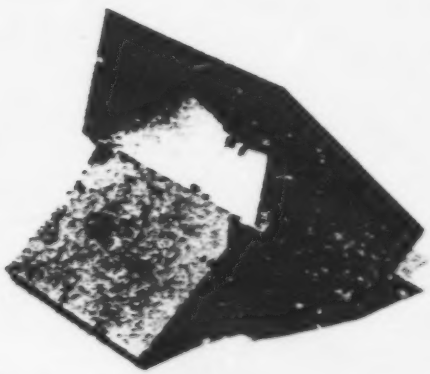

Figure 2—Oblique view of the type 1 trap. The trap is buried in the ground with the apron flush with the upslope surface.

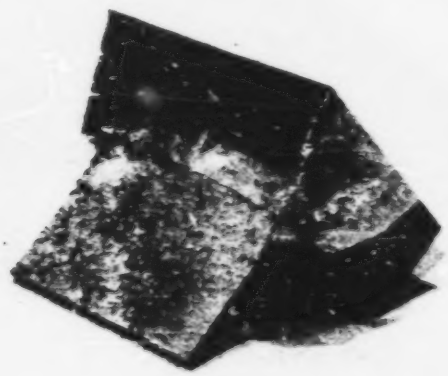

Figure 3—Oblique view of the type 1 trap fitted with a plastic liner.

to a collection bag. The type 2 trap, which has drain holes in the downslope corners to remove excess water, was not designed to be used with a plastic liner.

PRELIMINARY TESTING AND ASSESSMENT

Type 1 Trap

The type 1 trap was first field tested during winter 1982-83 in association with a prescribed burn in the Angeles National Forest, northeast of Los Angeles, California. A total of 30 traps were laid out in a roughly linear fashion, covering approximately 200 m of a chaparral-covered east-facing catchment, to assess the magnitude and timing of postfire sediment movement. A sample size of 30 points was expected to provide a reasonable estimate of the mean downslope transport rate along with a measure of sample variability for this small section of a single watershed. Captured debris was collected from the traps at irregular intervals over an 11-week period after the fire. The transported material was taken to the laboratory where it was oven-dried and weighed to the nearest gram.

For the total study period, the mean trap catch was 630 g of sediment, with a standard deviation of 330 g *(table 1)*. This would translate to a transport rate of 120 ± 63 cm^3 per centimeter of slope width per year. This generalized rate is undoubtedly exaggerated, as the high sediment production values are unlikely to persist after the initial sloughing of loose debris and the regeneration of the vegetation cover. Indeed, temporal results *(table 1)* indicate an immediate flush of transported sediment after the fire, as stabilizing vegetation was removed and soil structure was disturbed. This pulse of material, occurring as dry ravel immediately after the fire, quickly tapered off as the system adjusted to post-burn environmental conditions. A second flush of debris was associated with a major storm, the largest of that season, and the initiation of postfire erosion by water-driven transport processes. This second period of sediment movement again declined as the system adjusted to a new state of equilibrium. A graphic comparison of sediment delivery and precipitation inputs for the duration of the study period is shown in *figure 7*.

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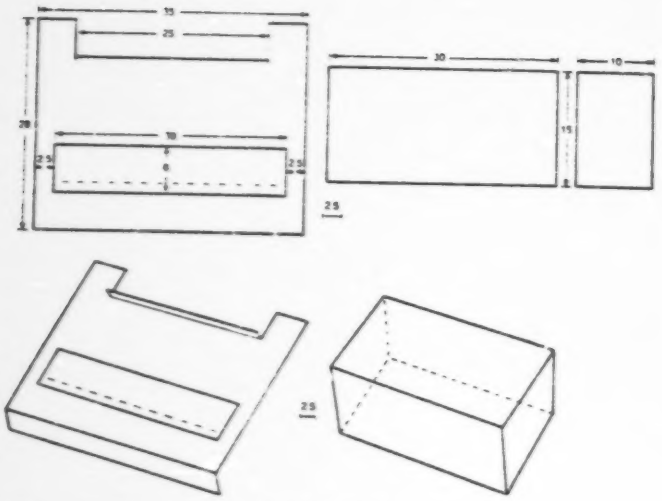

Figure 4—Schematic drawing of the type 2 trap with all dimensions in centimeters.

Figure 5—Oblique view of the type 2 trap showing the trough body detached from the apron.

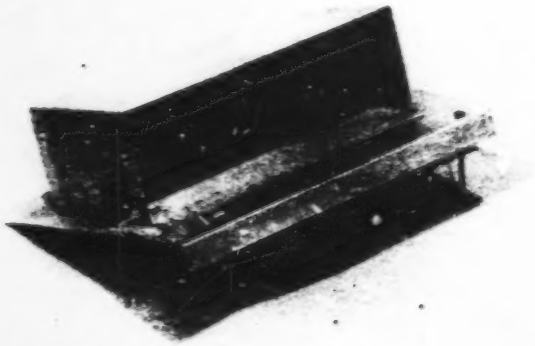

Figure 6—Oblique view of the assembled type 2 trap. The apron lies flat on the slope and is anchored by the pins.

The results confirm that this particular geomorphic system is spatially variable *(table 1)*. The total period standard deviation is slightly greater than 50 percent of the mean, but variation within an individual collection could be as high as 200 percent. These dispersion values are within the same range obtained using larger traps, reported above. The fact that smaller traps and larger traps produce data sets with similar variability presents a powerful argument in favor of smaller traps.

Another important pattern of sediment transport is the apparently random catch variability over time of a given trap compared with its neighbors. In addition to the temporal variation in debris production caused by the fire and precipitation, the relative magnitude of sediment recovery for an individual trap often changes radically from collection to collection. This indicates that the loci of sediment transport are continually shifting in response to local concentrations of energy expenditure (such as rills and small onslope debris flows) and the depletion of source areas. Hence, the low total period standard deviation in trap catch reflects an equalization of spatial debris contributions over time. Larger traps, sampling larger sections of a hillslope contour, probably would not have the sensitivity to reveal these subtler transport patterns.

The experiment at the Angeles prescribed burn site, while of limited scientific value, provided an excellent field test of trap effectiveness. Overall, the type 1 trap performance was a qualified success. Trap installation and sample collection were relatively quick and easy: the 30 traps took 10 person-hours to install, and a sample collection could be accomplished in as little as 2 hours (15 traps per hour). The amount of captured material was kept to a manageable level, which greatly facilitated the laboratory processing. This reduction in project logistics allowed for a much larger number of sample replicates than would have been possible using larger traps. Moreover, based on field observations, there was no evidence that the traps interfered with normal sediment delivery patterns. We believe, therefore, that the traps yielded a truly representative sample of onslope debris transport.

In the course of the project, however, three potential trap limitations were noted.

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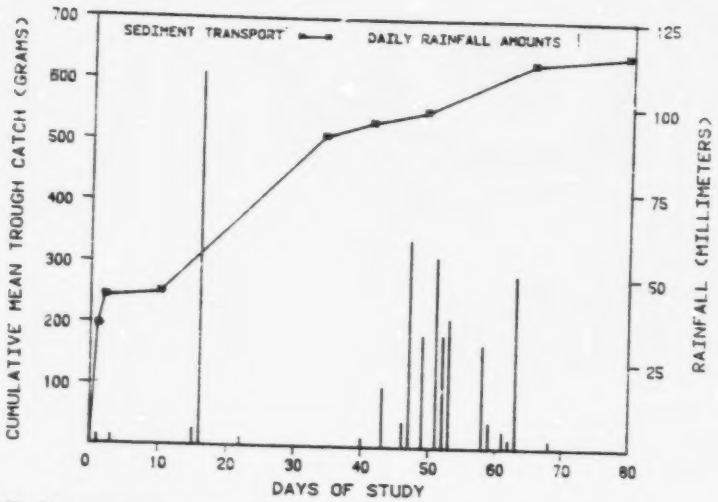

Figure 7—Sediment transport as grams of trap catch and daily rainfall amounts in millimeters for the 79-day study period.

Table 1—*Descriptive statistics for the evaluation of the Type 1 Trap performance, 1982-83, Angeles National Forest*

Days after the fire	Mean	Std. dev.	Range	
			High	Low
		grams		
1	186	121	509	20
2	46	32	116	3
10	11	17	75	1
34	252	195	608	39
41	24	21	70	1
49	18	23	99	1
65	77	174	967	8
79	16	16	57	2
Totals	630	330	1221	143

First, although at no time did the traps overtop, it is possible that during periods of low frequency sampling or of high magnitude transport rates, the catchment capacity of the traps would be exceeded. Second, when plastic liners are used, the traps could be flooded during large precipitation events, causing some floating organic material and suspended fines to be lost from the samples. Furthermore, the excess water must be removed from the samples by a laborious siphon or decantation procedure. Alternatively, if bags are not used, debris must be scooped out of the traps by hand, which is exceedingly difficult if the samples are saturated with water. Third, if transport becomes concentrated along flow lines or rills, the traps possibly could be undermined or the debris diverted away from the trap aperture. Under such circumstances, the traps could be abandoned, reducing the sample size and possibly introducing an element of bias, or they could be reset in a slightly different position, risking a measure of site disturbance. Also, resetting a trap might raise questions concerning the continuity of any subsequent data sets.

The original purpose of the plastic liners was to facilitate field collections. In practice, however, bags may be more of a hindrance than an aid in collecting samples. Besides the problem of removing excess water mentioned above, the plastic begins to disintegrate after prolonged exposure to sunlight. The alternative of cloth bags poses its own set of problems, as it is impossible to completely remove wet sediment from cloth collectors. A variation of this type 1 trap that eliminates the slot and liner assembly under the apron and has small drain holes at the bottom to remove excess water is now being used. In this modified type 1 trap, the approach apron is 30 cm wide—the full breadth of the trap aperture.

Type 2 Trap

The type 2 trap was first field tested in the upper reaches of the Santa Ynez River drainage, Santa Barbara County, California, in winter 1985-86, following the disastrous Wheeler Fire of the previous July. Five plots were located on separate hillslope facets and were sampled for surface transport by10 traps apiece. Aggregating the total contributions to these 50 traps for a 15-week period yielded a sample standard deviation that was 95 percent of the sample mean, although the variation within a single plot for a single collection was as high as 225 percent.

The overall performance of the type 2 traps was again a qualified success. Trap installation and sample collection were even easier than with the type 1 trap. Because the trough bodies did not have to be buried in the ground, installation time for the 50 traps was less than 6 person-hours. And because the trough body is detachable from the apron, sample collections could be completed in about 2 hours (25 traps per hour). The downslope drain holes adequately removed excess water from the samples with only a small loss of debris. No cones of sediment originating from the drain holes were observed below the traps. The amount of sediment inevitably lost through these holes appears negligible compared with the bulk catch, although the loss is undoubtedly skewed towards the finer particle sizes. However, the capacity of the type 2 trap is approximately 20 percent less than that of the type 1 model, thereby increasing the chances of this type of trap overtopping. Also, the type 2 traps are no less susceptible to being undermined by erosion.

APPLICATION

The application of the various trap types to a particular project depends on the nature of the study. The type 1 traps with the plastic liners are suitable for studies involving high frequency sampling (time periods less than 2-3 weeks) or requiring the full range of particle sizes (as long as flooding of the bag does not occur), or both. The modified type 1 traps with drain holes and no plastic

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bags are more suitable for projects with longer collection periods or on areas with higher transport rates, or both. The type 2 traps effectively cover a broad spectrum of sampling frequencies and potential transport rates. They are also much easier to use than the type 1 traps, requiring less time for both field installation and sample collection. However, because of their smaller capacity, the type 2 traps may not be suitable for sites with extremely high sediment transport rates. Currently, about 600 traps of both types are being used by several groups of researchers and land managers throughout California.

ACKNOWLEDGMENTS

We thank the following individuals for their critical comments and technical review of the manuscript: Edward A. Keller, Department of Geological Sciences, University of California at Santa Barbara; Phillip S. Kane, Department of Geography, California State University, Northridge; and Station staff members Robert B. Thomas, Arcata; James A. Baldwin, Berkeley; and Susan G. Conard and Allan G. Campbell, Riverside.

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